APPENDIX G. REAL-SCALE PLATFORM AREA MOCK-UP EXPERIMENTS

This appendix contains additional data on the fire growth in the full-scale mock-up fire tests described in Chapter 4, and is compiled here for reference. Some material from Chapter 4 is repeated for the benefit of the reader.

G.1 INSTRUMENTATION AND EXPERIMENTAL PROCEDURE

The test room was equipped with thermocouples, video cameras, heat flux gauges, bi-directional probes, and gas extraction probes to measure carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), and hydrogen cyanide (HCN). In addition, fixed temperature and rate-of-rise heat detectors were installed, as were sprinklers. In one test, the sprinklers were not supplied with water but were monitored for time to activation. Figure G-1 is a schematic floor plan of the instrumentation positions.

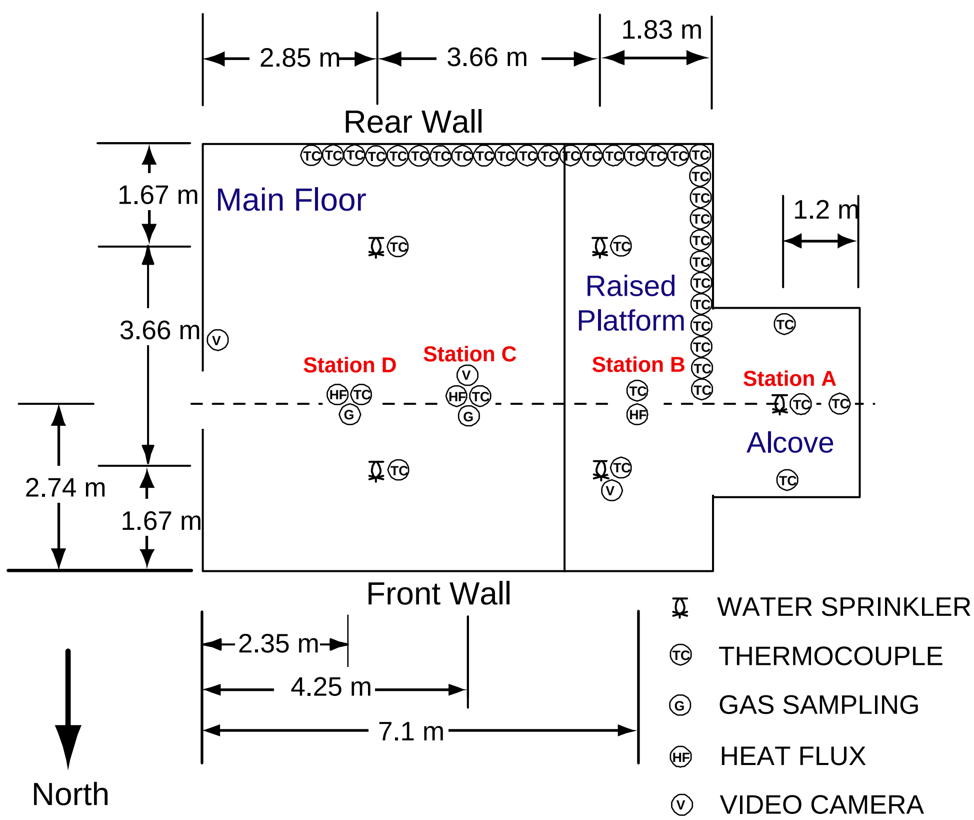

Figure G-1. Schematic floor plan with instrumentation positions.

Two full-scale experiments were conducted: one with and one without sprinklers. Prior to ignition, each of the analyzers was zeroed and calibrated and the data acquisition system and videos were started to collect background data. Data for 194 channels were recorded at one second intervals. Ignition of the foam was initiated with electric matches simultaneously at two locations on the outer corners of the alcove, 1.8 m above the raised floor area. The fire gases that emerged from the open door on the south end of the test room were captured in the hood of the oxygen depletion calorimeter. The data were reduced and plotted versus time for each of the channels.

G.2 TEMPERATURE MEASUREMENTS

The temperatures were measured with 0.51 mm nominal diameter bare bead, Type K thermocouples. The thermocouple array over the platform floor area had a thermocouple located at 0.025 m, 0.30 m, 0.61 m, 0.91 m, 1.22 m, 1.52 m, 1.83 m, 2.13 m, 2.44 m, 2.74 m, 3.05 m, 3.35 m, and 3.66 m below the ceiling.

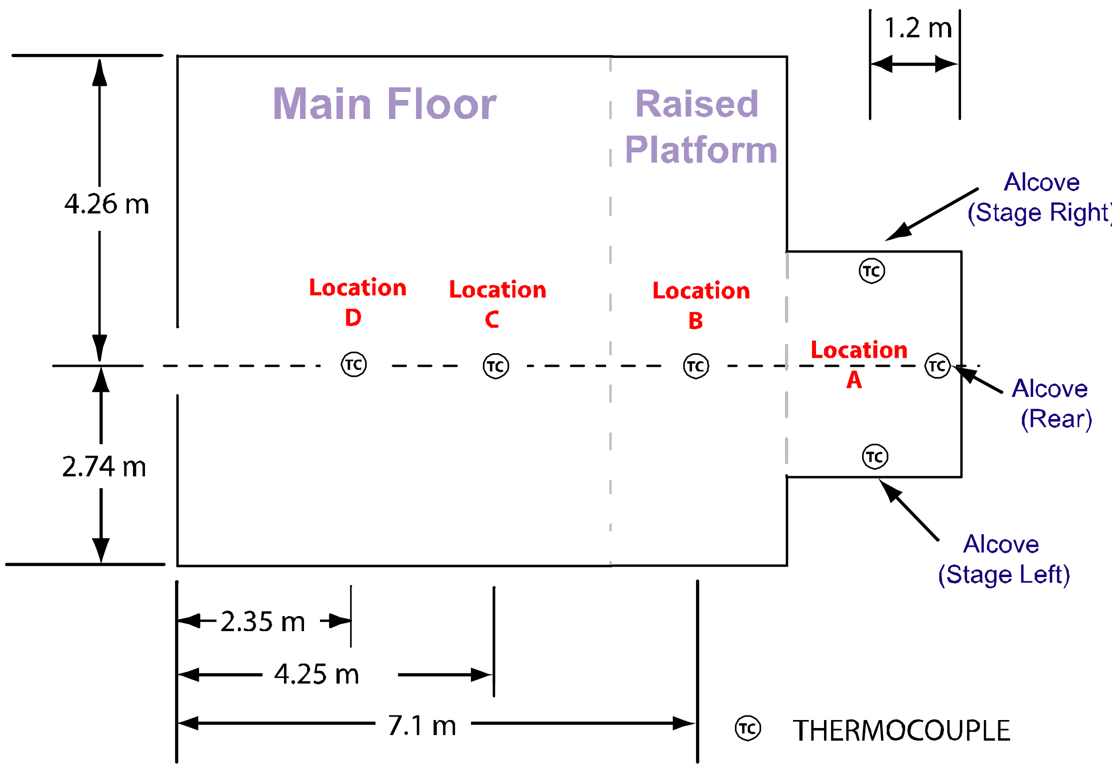

Figure G-2. Schematic floor plan with thermocouple positions.

For the platform floor thermocouple array, the thermocouple that was located 3.66 m below the ceiling, was positioned on the platform floor. The two-thermocouple arrays on the main floor also had a thermocouple located at 3.66 m below the ceiling, but in each case, the thermocouple was positioned 0.15 m above the main floor. Vertical thermocouple arrays were installed in the center of each wall of the alcove. Each array had a thermocouple located at 0.30 m, 0.61 m, 0.91 m, 1.22 m, 1.52 m, and 1.83 m below the ceiling of the alcove. A horizontal thermocouple array was installed 0.30 m below the ceiling. The array began at the centerline of the alcove opening and continued north along the rear wall, and then followed the platform wall west for 6.1 m. The thermocouples were spaced approximately 0.30 m apart. In addition, thermocouples were located adjacent to the sprinklers. Temperatures versus time are plotted in Figures 4-22 through 4-28.

Thermocouples were installed near the ignition points on both sides of the alcove opening, 1.8 m above the floor of the platform. As shown in Figure G-3, in the unsprinklered compartment burn, the temperatures near the ignition point stage-left began to increase rapidly in less than 10 seconds and it then dropped to about 100 ^{o}C. After about 30 seconds, both stage-right and stage-left thermocouples began to increase to temperatures in excess of 600 ^{o}C. The initial peak and subsequent drop and then rapid increase were probably due to movement of the flame sheet or thermal plume. If the thin flame sheet was near the thermocouple bead, a high temperature would be recorded, but if the plume of hot gases moved and caused the bead to be in the fuel rich interior of the plume, lower temperatures could have been recorded.

Slightly different temperature behavior was recorded in the sprinklered test (Figure G-4). Initially both stage-left and stage-right temperatures increased rapidly as the stage-left thermocouple had in the unsprinklered test, but as sprinklered burn temperatures dropped back to about 100 ^{o}C, the sprinklers activated and caused the temperatures to decrease to near ambient temperatures.

Three thermocouple arrays were installed in the alcove, stage-right wall, stage-left wall, and rear wall of the alcove (Figures G-5, G-7, and G-9). The temperatures recorded by each of three thermocouple arrays were similar. In the unsprinklered test burns, the temperatures began to increase within 30 seconds after ignition. By 60 seconds to 70 seconds after ignition, temperatures exceeded 800 ^{o}C . In the sprinklered compartment burns (Figures G-6, G-8, and G-10), the temperatures also began to increase in approximately 30 seconds, but the temperatures had only increased to about 40 ^{o}C to 60 ^{o}C before the sprinklers activated and the temperature gradually decreased to ambient temperatures.

One thermocouple array was installed from ceiling to floor on the platform, Location B. For the unsprinklered case (Figure 4-22), the temperature at the ceiling began to increase within 10 seconds and continued to increase to over 800 ^{o}C in approximately 50 s. As the hot gases began to form an upper layer, the layer began to descend and in just over 110 seconds, the temperature at the floor of the platform had increased to over 600 ^{o}C . In less than 60 seconds, the temperature had exceeded 50 ^{o}C at the 1.4 m (4.5 ft) above the floor (2.4 m below the ceiling) elevation. For the sprinklered test burn (Figure 4-25), the ceiling thermocouple recorded temperatures in excess of 360 ^{o}C in less than 25 seconds, but had decreased to ambient in less than 40 seconds. The activation of the sprinklers caused the other thermocouples at lower elevations to record near ambient temperatures throughout the test burn.

The thermocouple array at Location C was installed 6.7 m from the foam covered platform wall. Location C thermocouples were an additional 3 m further away from the platform wall than the thermocouples at Location B. Since the thermocouples at Location C were further away from the fire source than the thermocouples at Location B, the temperatures might be expected to increase more slowly than at Location B. For the unsprinklered thermocouples (Figure 4-23), the temperatures did require slightly longer to begin to increase, about 15 seconds, and required approximately 70 seconds to reach peak temperatures of 800 ^{o}C. The temperatures at 3.6 m below the ceiling did not begin to increase until 60 seconds after ignition and then the temperatures reached peak values of approximately 100 ^{o}C in 90 s. The temperatures near the floor at Location C were significantly lower that the values recorded at the floor on the platform, Location B. In less than 70 seconds, the temperature had exceeded 50 ^{o}C at the 1.4 m (4.5 ft) above the floor (2.4 m below the ceiling) elevation. For the sprinklered test burn (Figure 4-26), the ceiling temperatures reached a peak temperature of 170 ^{o}C in about 20 seconds and declined to

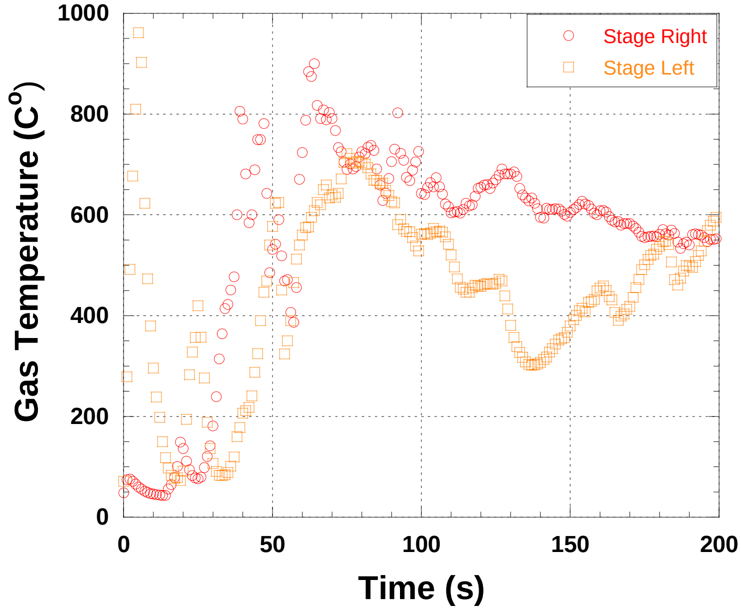

Figure G-3. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned on right and left side of alcove opening 1.8 m (5.t ft) above platform floor at ignition points.

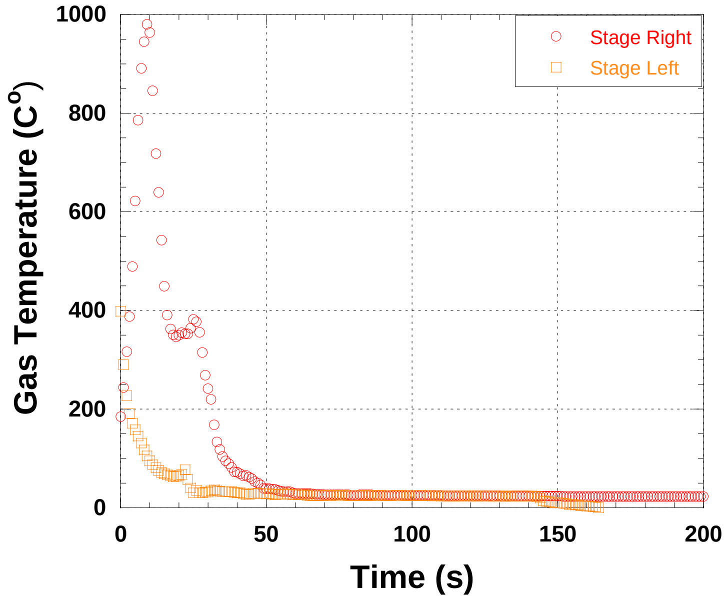

Figure G-4. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned on right and left side of alcove opening 1.8 m (5.5 ft) above platform floor at ignition points.

near ambient temperatures within 60 seconds. Thermocouples at lower elevations appeared to remain at near ambient temperatures throughout the test.

The thermocouple array at Location D was installed 8.5 m from the foam covered platform wall. Location D thermocouples were an additional 1.8 m further away from the platform wall than the thermocouples at Location C. Again, as the distance between the thermocouple array and the fire increased, the temperatures were expected to increase more slowly that the arrays that were located closer to the fire. For the unsprinklered thermocouples (Figure 4-24), the temperatures did require slightly longer to begin to increase, about 20 seconds, and required approximately 80 seconds to reach peak temperatures of 700 ^{o}C. The temperatures at 3.6 m below the ceiling did not begin to increase until 70 seconds after ignition and then the temperatures reached peak values of approximately 100 ^{o}C in 90 s. The temperatures near the floor at Location D were about the same as that the values recorded at the floor on the platform, Location C. In less than 70 seconds, the temperature had exceeded 50 ^{o}C at the 1.4 m (4.5 ft) above the floor (2.4 m below the ceiling) elevation. For the sprinklered test burn (Figure 4-27), the ceiling temperatures reached a peak temperature of 130 ^{o}C in about 20 seconds and declined to near ambient temperatures within 60 seconds. Thermocouples at lower elevations appeared to remain at near ambient temperatures throughout the test.

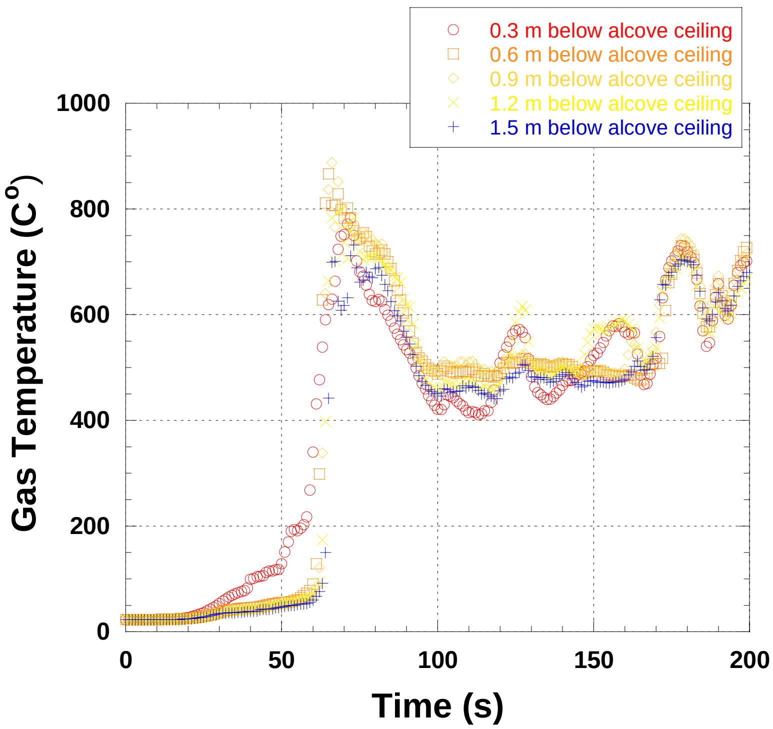

Figure G-5. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned in Alcove (A-SR) on wall (stage-right).

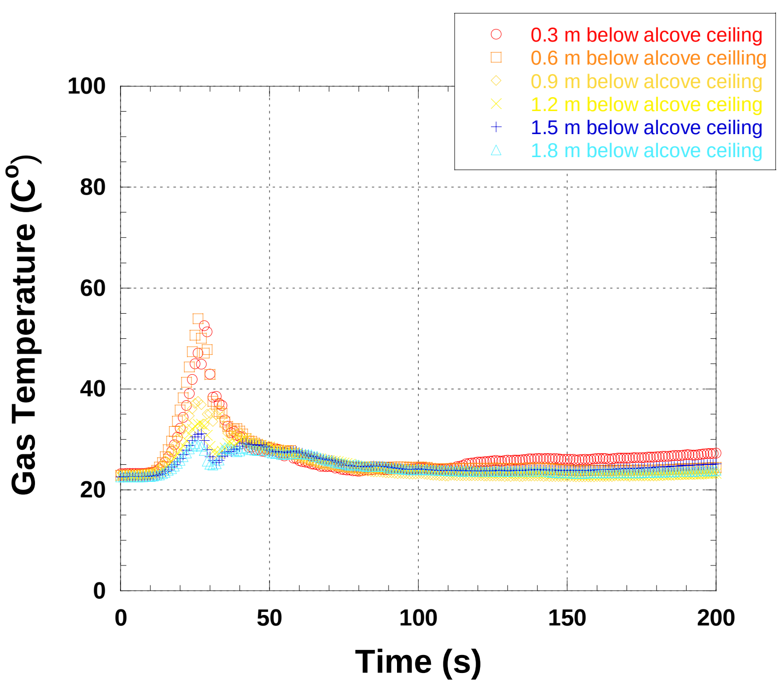

Figure G-6. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned in Alcove (A-SR) on wall (stage-right).

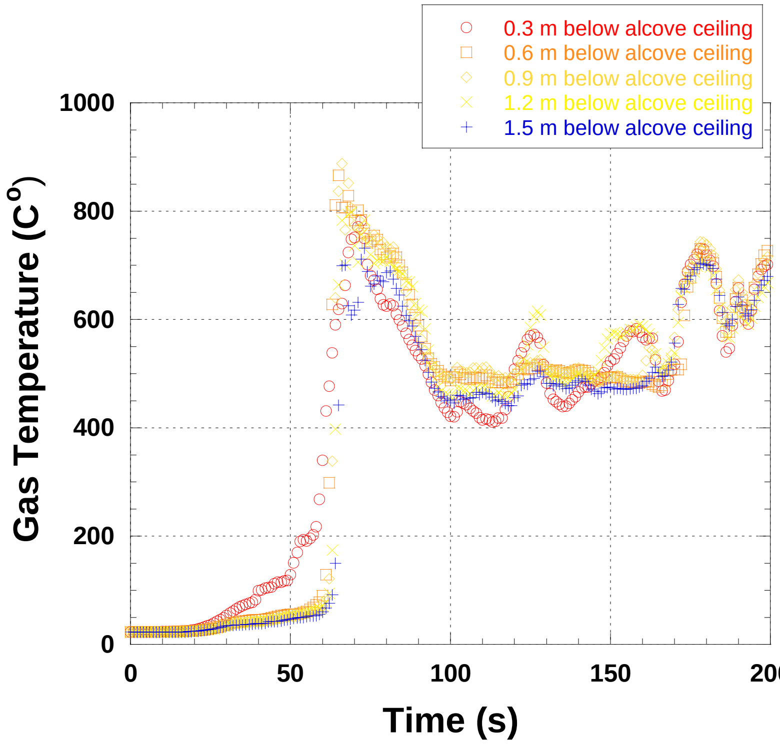

Figure G-7. Unsprinklered Mockup Test. Alcove (A-SB) on rear wall .

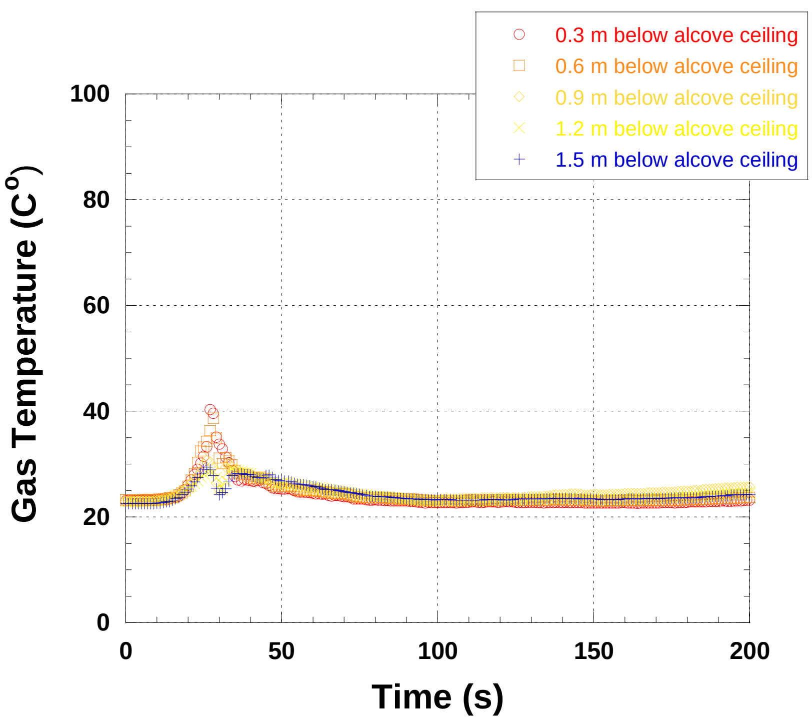

Figure G-8. Sprinklered Mockup Test. Alcove (A-SB) on rear wall.

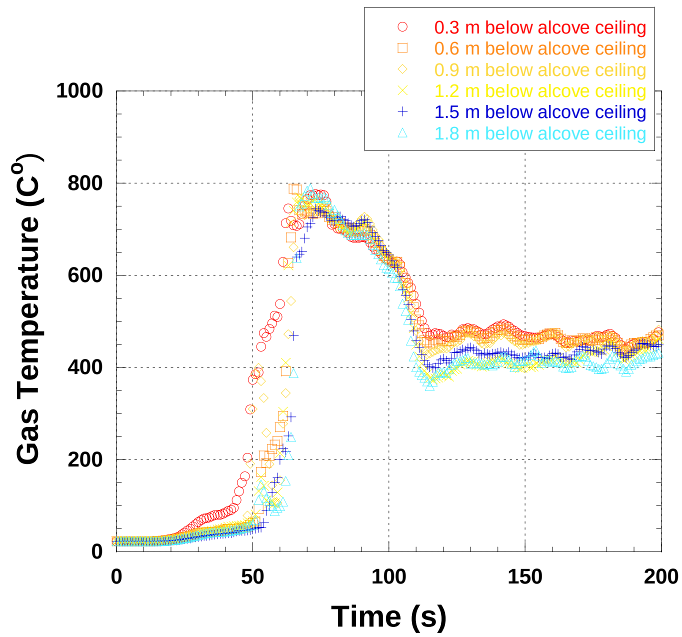

Figure G-9. Temperatures versus Time for Unsprinklered Mockup Test. Thermocouples positioned in Alcove (A-SL) on wall (stage-left).

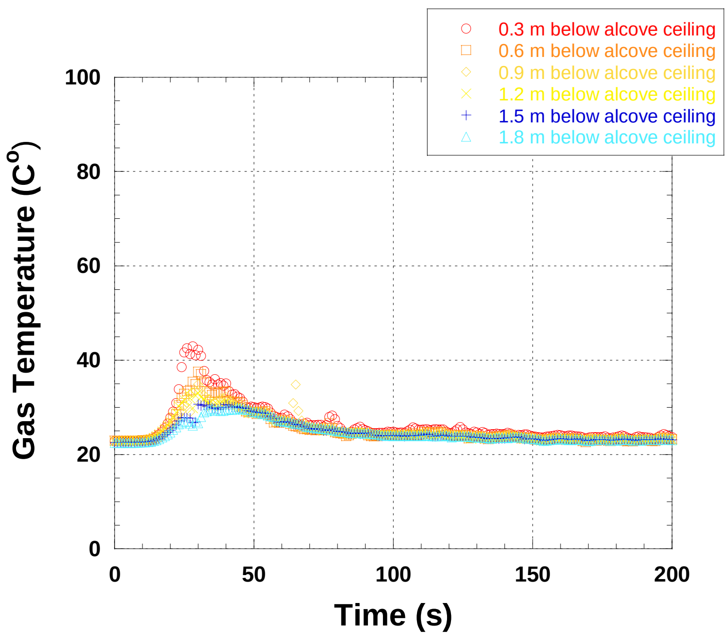

Figure G-10. Temperatures versus Time for Sprinklered Mockup Test. Thermocouples positioned in Alcove (A-SL) on wall (stage-left).

G.3 GAS MEASUREMENTS

The gas sampling ports were co-located with the heat flux sensors on the main floor area (Figure 4-63). The gases were pulled through 9.4 mm ID tubing to chemical analyzers after passing through moisture and particulate filters. Carbon monoxide and carbon dioxide concentrations were monitored using non-dispersive infrared gas analyzers while the oxygen concentrations were measured using paramagnetic analyzers. Hydrogen cyanide concentrations were monitored using impingers and real-time gas analyzers, which utilized an off-the-shelf cyanide combination electrode. Each impinger utilized 0.1 M KOH as the trapping solution and samples were analyzed according to NIOSH Method 7904 [1]

During the sampling process, the gas sample for the oxygen, carbon monoxide, and carbon dioxide analysis was drawn through a cold trap which removed the water vapor. The oxygen, carbon monoxide, and carbon dioxide concentrations were recorded by each analyser on a dry or Orsat basis. The hydrogen cyanide sample gas utilized a different sampling train and did not pass through a cold trap. Since the hydrogen cyanide samples were monitored on a wet basis, the oxygen, carbon monoxide, and carbon dioxide concentrations were corrected for the water removed by the cold trap. For complete combustion of low methane, two moles of water are generated for each mole of carbon dioxide produced. For larger hydrocarbon molecules, the ratio of moles of water produced for each mole of carbon dioxide decreases to a 1:1 ratio, assuming the carbon to hydrogen ratio approaches 1:2. It was assumed that for every mole of carbon dioxide or carbon monoxide generated that a mole of water was also generated. This assumption was used to correct the dry or Orsat basis analyzer data to a wet basis. By adding the water vapor back into the gas sample, the concentrations of oxygen, carbon monoxide, and carbon dioxide decreased. The relative uncertainty in the volume fraction measurement is estimated to be +/- 20 %.

Carbon dioxide gas concentrations versus time are plotted in Figures G-12 and G-13. For the unsprinklered tests, carbon dioxide concentrations at both Locations C and D began to increase 80 seconds after ignition and reached peak values of 12 % approximately 100 seconds after ignition. The fluctuations that were observed in the oxygen concentrations were also seen in the carbon dioxide concentrations. For the sprinklered compartment experiments, the carbon dioxide concentrations did not appear to increase above ambient concentrations.

G.4 HEAT FLUX MEASUREMENTS AND HEAT DETECTOR RESPONSE

Three elliptical radiometers were installed in the ceiling of the test cell viewing downward at Location B, C, and D (Figure G-14). In addition to the radiometer at Location B, a total heat flux gauge with an upward view was installed flush with the platform floor. At Locations C and D, two additional total heat flux gauges were installed 1.5 m above the floor. One total heat flux gauge was position to have an upward view, while the other gauge had a view of the alcove. The heat flux sensors were water-cooled Schmidt-Boelter type transducers. Heat flux versus time is plotted in Figure G-15 through Figure G-23. The uncertainty in the heat flux values reported is estimated to be +/- 20 %.

The three radiometers were plotted together in Figure G-15. As the distance between the radiometer and the fire source increased, the peak radiation flux decreased. For Locations B, C, and D, peak radiation levels were approximately 60 kW/m^2, 50 kW/m^2, and 20 kW/m^2, respectively.

Unsprinklered and sprinklered radiation and total heat fluxes are plotted in Figures G-16 through G-23. In each sprinklered test at Locations C and D, neither radiation nor total heat flux reached significantly higher fluxes than background. Only at Location B, was there a slight increase in radiation or total heat flux at about 20 s.

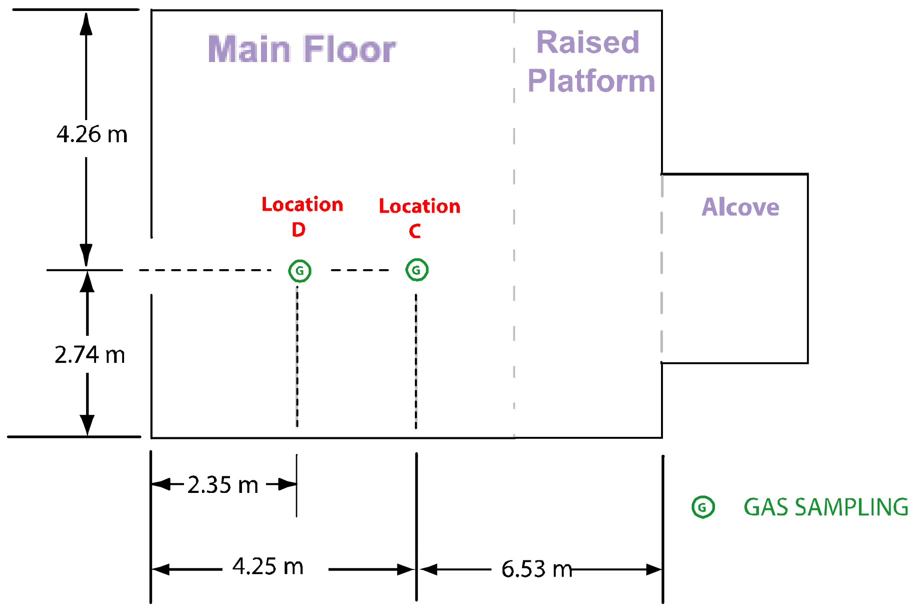

Figure G-11. Schematic floor plan with gas sampling locations.

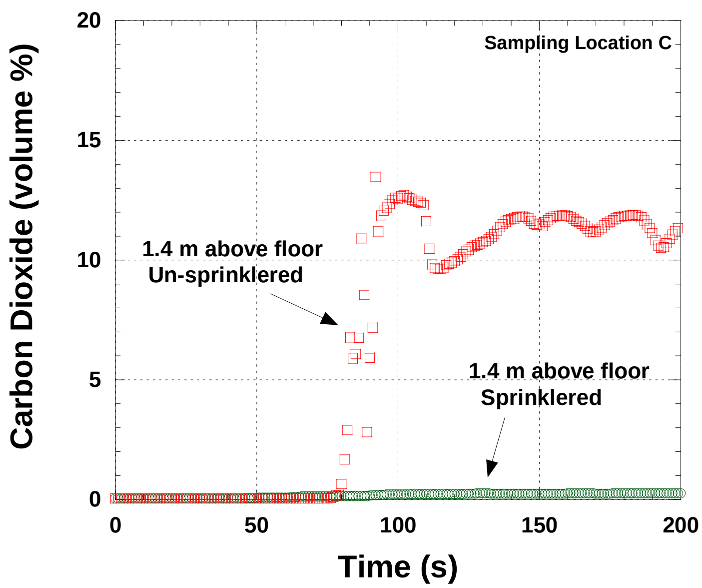

Figure G-12. Carbon dioxide volume fraction versus time for unsprinklered and sprinklered mockup test. Gas sampling probe positioned on main floor (Location C) at 1.4 m (4.5 ft) above floor.

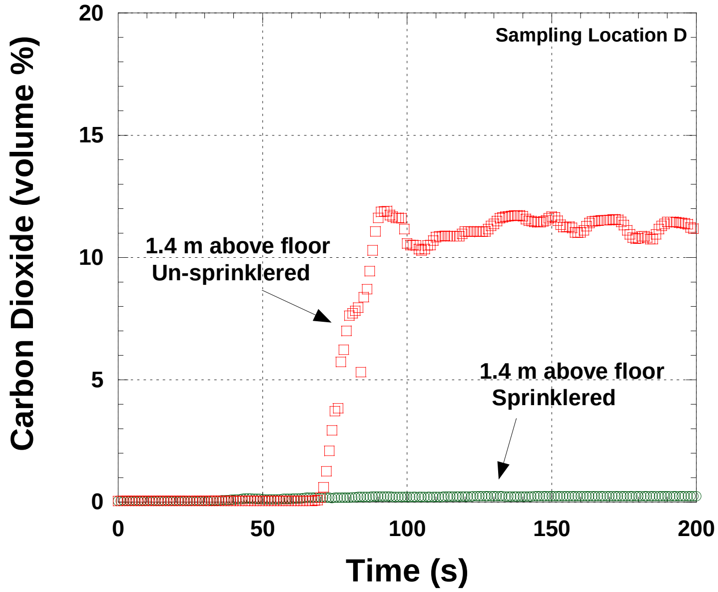

Figure G-13. Carbon dioxide volume fraction versus time for unsprinklered and sprinklered mockup test. Gas sampling probe positioned on main floor (Location D) at 1.4 m (4.5 ft) above floor.

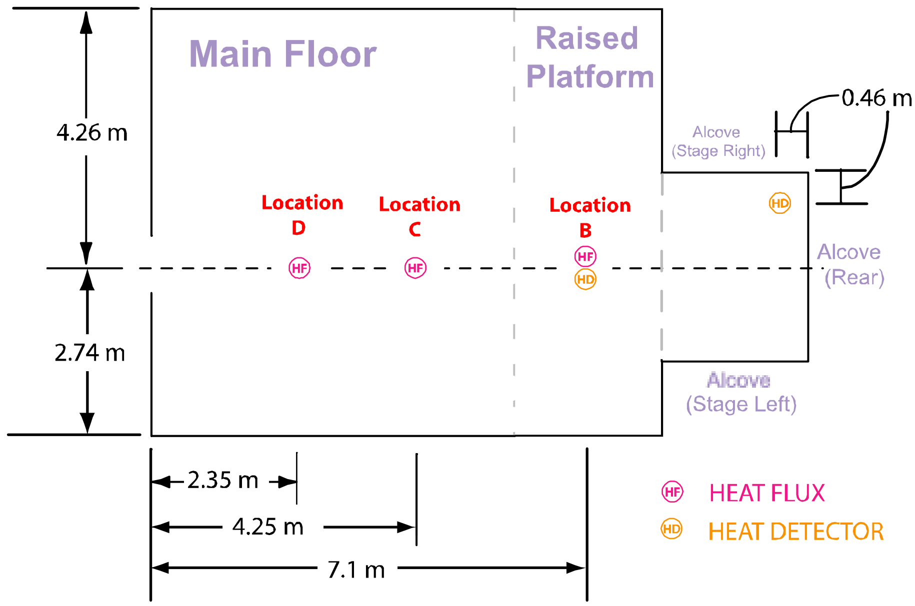

Figure G-14. Schematic floor plan with heat flux and heat detector locations.

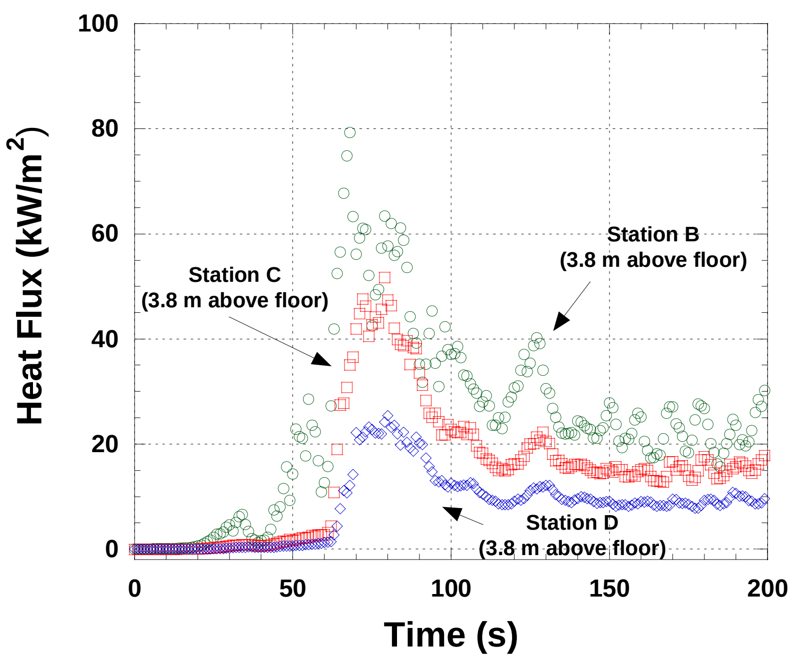

Figure G-15. Radiation fluxes versus time for unsprinklered mockup test. Gauges positioned flush with ceiling (3.8 m above floor) at locations B, C, and D.

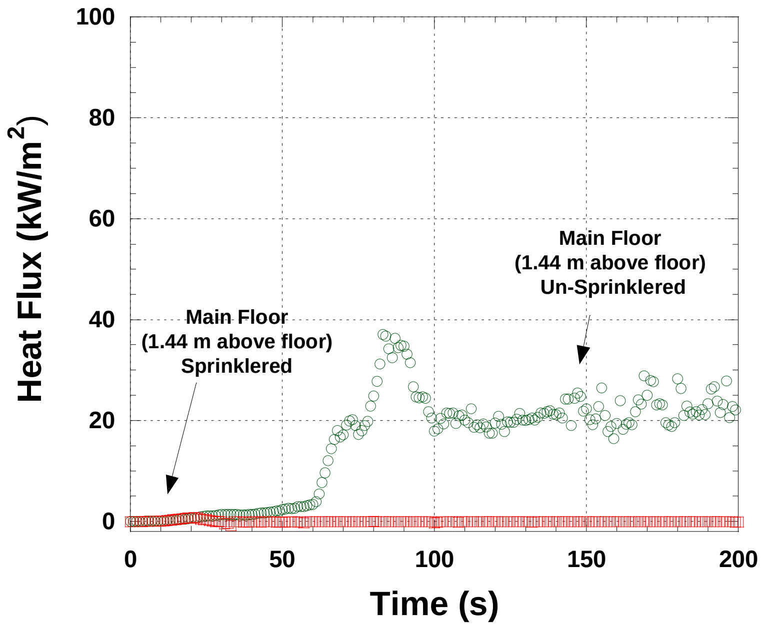

Figure G-16. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned facing alcove (1.44 m above floor) at location C.

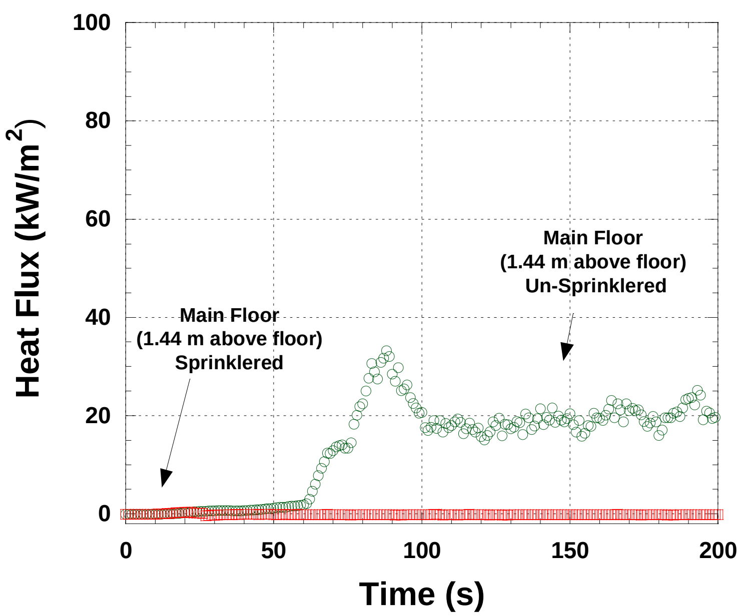

Figure G-17. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned facing alcove (1.44 m above floor) at location D.

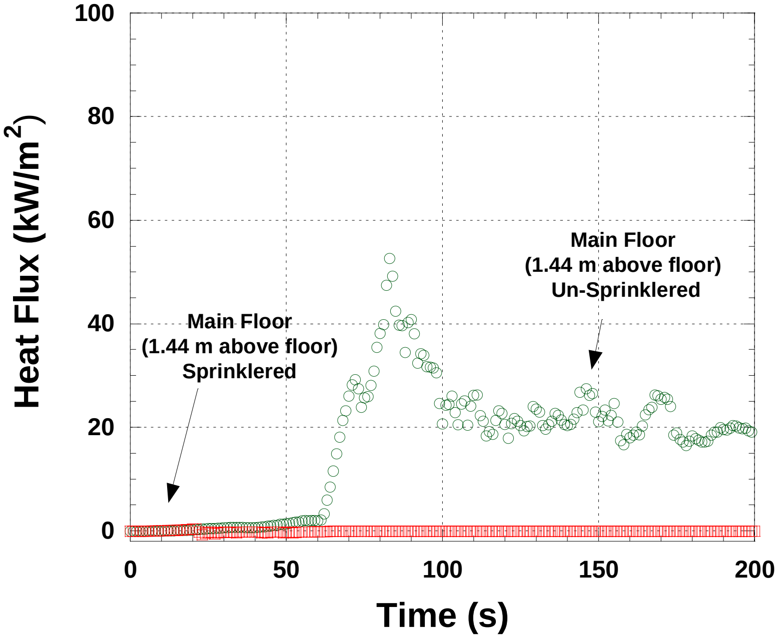

Figure G-18. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned facing ceiling (1.44 m above floor) at location C.

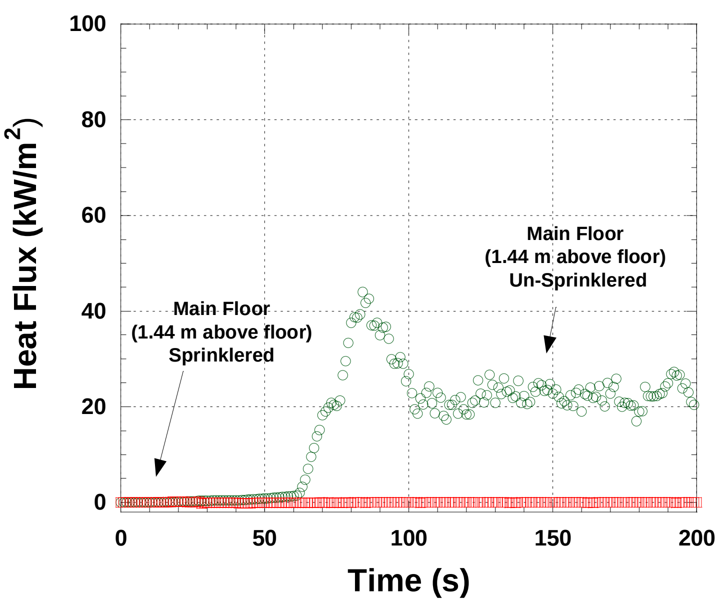

Figure G-19. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned facing ceiling (1.44 m above floor) at location D.

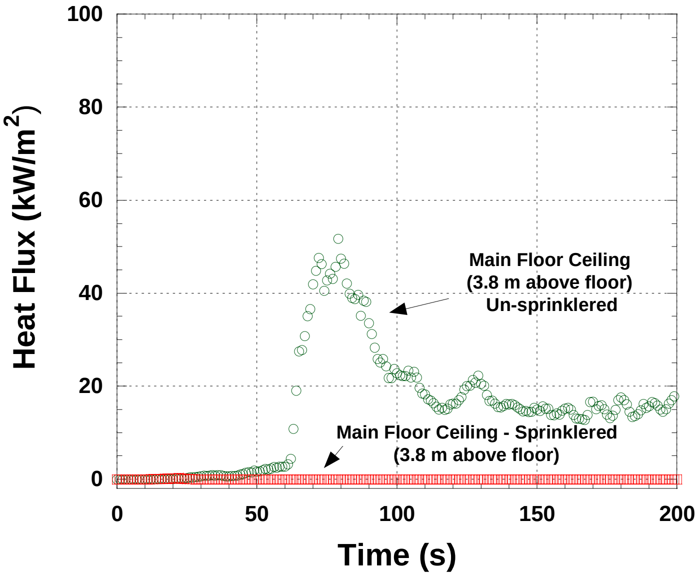

Figure G-20. Radiation Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned flush with ceiling, facing down (3.8 m above floor) at location C.

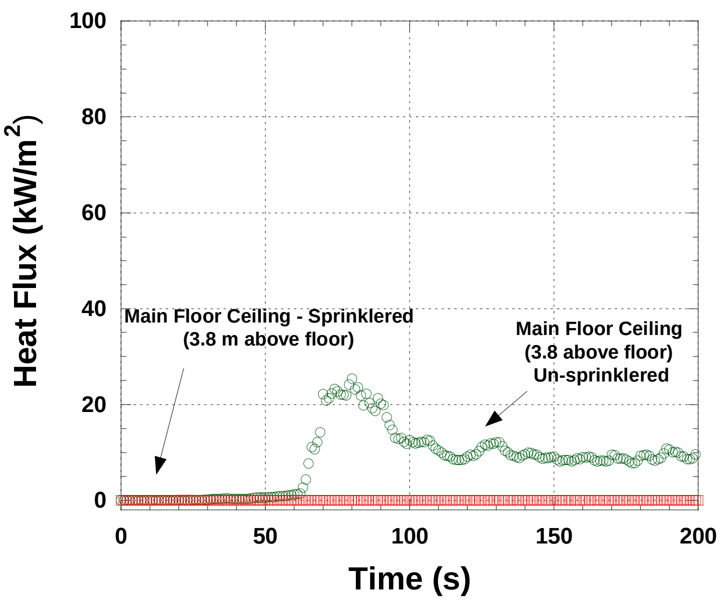

Figure G-21. Radiation Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned flush with ceiling, facing down (3.8 m above floor) at location D.

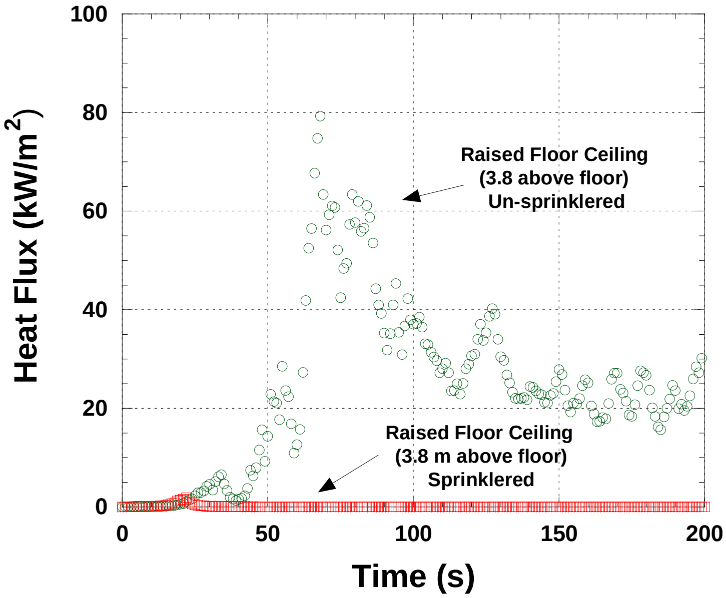

Figure G-22. Radiation Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned flush with ceiling, facing down (3.8 m above floor) at location B.

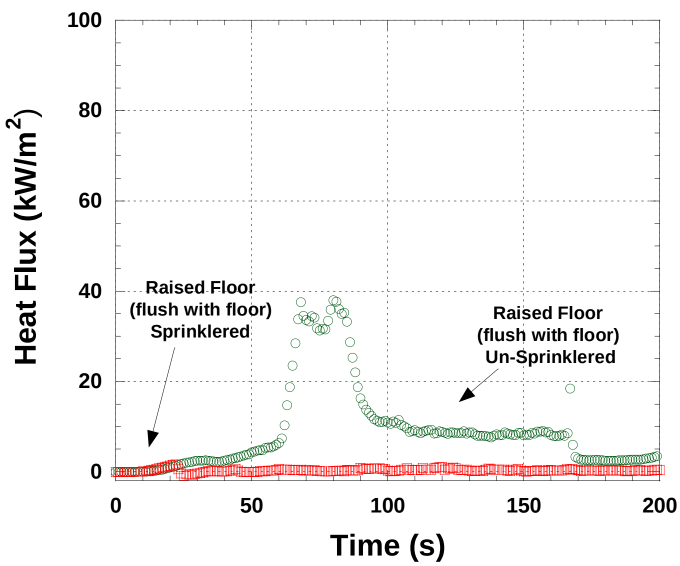

Figure G-23. Heat Fluxes versus Time for Unsprinklered and Sprinklered Mockup. Gauges positioned flush with raised floor of platform, facing up at location B.

G.4 REFERENCES FOR APPENDIX G

1. "Cyanides, Aerosol and Gas, Method 7904," *NIOSH Manual of Analytical Methods*, Fourth Edition, 8/15/94.